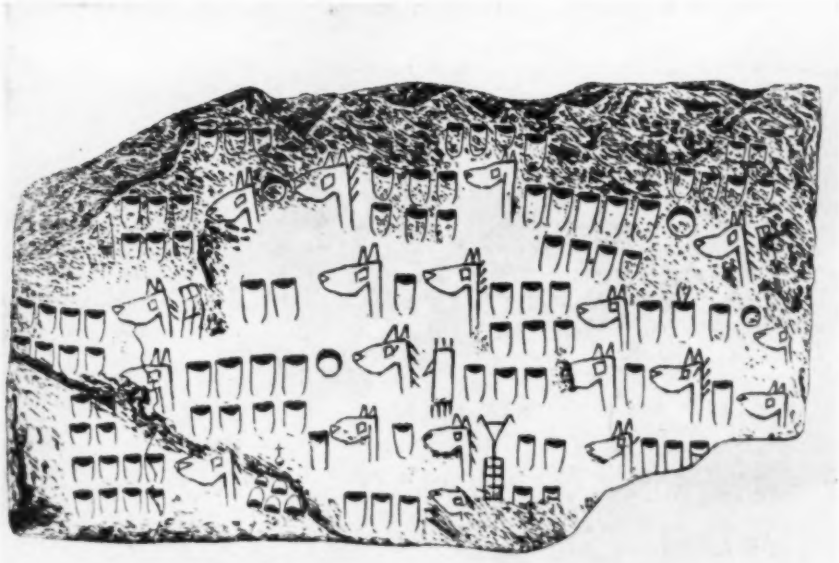
PEARL

The Journal of HEREDITY



PAGE FROM A STUD-BOOK OF FIFTY CENTURIES AGO

(SEE PAGE 233)

Fertility of Cereal Genus Hybrids

"Pale Midrib" Maize

Embryology of Drosophila

A Fused Finger-Joint Inherited

"Curly-Haired" Rats

Why Human Beings Differ

"Who's Who" Among the Genes

The Genetics of Maize

VOLUME 26 JUNE, 1935 NUMBER 6

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COMING

Why the Declining Tuberculosis Death Rate?

Is the dramatic reduction in the death rate from tuberculosis due to Public Health activities — or to other causes? This problem is one of far-reaching importance. If other factors than Public Health activities have been of primary importance it is possible that Public Health methods should be drastically modified.

✣

Wry-tail Inherited

A wide spread, but ordinarily rather rare, defect in cattle demonstrated to be a unit character.

✣

Sex Determination in Bees and Wasps

The bees do things differently. Most father bees have no father—but not all. A virgin can have a large family without straining the dictionary as long as all her children are sons. These and other interesting peculiarities make a rather complicated and most interesting problem for genetic analysis.

✣

Coffee Breeding in Brazil

Progress in a program of applying genetic methods to the improvement of one of Brazil's greatest industries.

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A SINGLE JOINT FUSED

Frontispiece

Skiagraph of the right hand of the young man described in the text, showing the fusion of the joint between the middle and terminal phalanges of the index finger. In this family eight individuals have had this joint fused, all the other joints being normal. The minute detail with which such deviations from the normal are passed on from generation to generation is one of the most interesting features of heredity. In most of the other families showing fused finger joints, the ring finger is most often affected, and the index finger is generally normal. This reversal of the situation found in other families is an excellent example of the specificity of genetic processes.

INHERITANCE OF A FUSED JOINT IN THE INDEX FINGER

Ankylosis of the Distal Interphalangeal Joint of the Index Finger

ARCH E. COLE
Department of Anatomy, University of Louisville Medical School

THE literature contains many reports of congenital absence of interphalangeal joints (symphalangism*). Practically all of these reports deal primarily with ankylosis of the interphalangeal joints of the fingers; the condition of the joints of the toes is either overlooked completely or mentioned only in a general way. In the majority of the cases reported the ankylosis involved the proximal interphalangeal joints.

The tendency to familial recurrence of ankylosis of the proximal interphalangeal joints of the fingers has been repeatedly demonstrated (Walker,[14] Cushing,[2] Brügger,[1] Elkin,[3] Wilmoth[15] and many others). Cushing followed the defect through seven generations, involving 302 individuals, of whom 25.8 per cent possessed ankylosed proximal interphalangeal joints. The defect, he concluded, was inherited as a simple mendelian dominant. The other reports did not contain a sufficient number of cases to justify any conclusions concerning the mode of inheritance.

More rarely does the ankylosis involve the distal interphalangeal joints, and consequently fewer reports of the condition are to be found in the literature. Cushing is inclined to the belief that the cause for the relative infrequence of terminal interphalangeal joint involvement is correlated with the time of ossification of digital segments. Mall[9] pointed out that the terminal phalanges are the first to ossify, followed by those of the proximal row, and that the segments of the middle row are the last to show centers of ossification. Furthermore, in any row, the pre-axial or radial digits show centers of ossification before those of the post-axial side. If the failure of development of a functional joint were due to an inhibitory factor capable of acting only until a certain stage of differentiation took place, such an explanation of relative frequency of proximal and distal joint malformations might be plausible, for the greater the interval of undifferentiation the longer the time which the inhibiting factor would have for acting. This might also account for the fact that in all recorded cases of distal interphalangeal joint ankylosis which could be found, the little finger was involved over twice as many times as the index finger.

Stintzing,[13] Hoffman,[5] Klausner,[8] and Wolf[16] have reported instances of ankylosis which involved only the distal interphalangeal joints. Of these, the first three deal with cases in which other parts of the body showed defective development and in which there was no hereditary history. In the case reported by Wolf the defect involved only the distal interphalangeal joint of the little finger. The malformation was hereditary, appearing in eight individuals in four generations, the same joint being affected in each instance.

Several reports which have dealt primarily with congenital ankylosis of the proximal interphalangeal joints have mentioned similar defects in distal joints (Sklodowski,[12] Kirmisson,[7] Joachimsthal,[6] Pagenstecher,[11] Walker,[14]

* The term symphalangism is used by some authors to apply only to ankylosis of the proximal interphalangeal joints; by others, to either the proximal or distal interphalangeal joints. The latter usage seems preferable.

Engel,[4] Miller,[10] Wilmoth[15]). The hereditary nature of the defect is evidenced in the reports submitted by Walker, Engel, and Wilmoth, although in no instance is the number of individuals exhibiting the anomaly sufficiently large to draw any conclusion concerning the mode of inheritance.

There recently came to my attention a young man, twenty-six years of age, a university student, who exhibited a complete absence of the distal interphalangeal joint of both index fingers. The loss of this joint in no way interferred with his ability to do careful laboratory work. The condition, according to his parents, was present at birth.

The external appearance of the defective digits is not unlike the normal. The fingers are of normal length and shape; the nail fully formed. The transverse skin-folds and furrows are present but not so pronounced as on the other fingers. On palpation the terminal and middle phalanges appear to be well formed; the lateral prominences are easily felt. Skiagraphs (Frontis.) of the hands show that the terminal and middle phalanges of the index fingers, although well formed and of normal length, are fused together, in a straight line, by bony ankylosis. Viewed dorsally the joint site is indicated by a marked constriction between the head of the middle phalanx and the base of the terminal one. The lateral prominences on the base of the terminal phalanx are conspicuous. (Fig. 1). The union between the phalanges is made up of cancellous bone, trabeculae of which can be followed from one bone to the other. The compact cortical bone appears to be thinned out except along the sides. This is particularly true on the left hand.

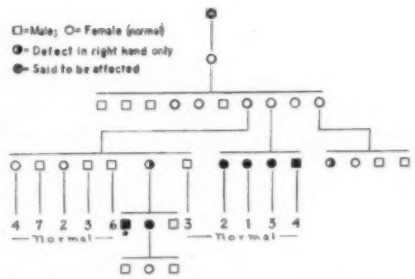
The terminal and middle phalanges of the fourth and fifth toes of the right foot and of the fifth toe of the left foot are fused. The joint site is indicated in each case by a groove. Both interphalangeal joints of the second toe of each foot are in a partially flexed position. The toes, however, can be passively extended and skiagraphs show no bony union at the joint site.

DETAIL OF FUSED JOINTS
Figure 1

Enlarged skiagraph of the tip of the index finger of the right hand showing the entire absence of a joint between the middle and terminal phalanges.

Aside from the ankyloses of the distal interphalangeal joints described above no other defects, bony or otherwise, are apparent.

The malformation is common in the young man's family where its bearers are referred to as "stiff-fingered" in-



TRANSMITTED THROUGH FEMALE LINE

Figure 2

Pedigree of the family in which congenital bony ankylosis of the distal interphalangeal joint of the index finger has occurred in eight individuals. The transmission has always been through the female line but two males show the defect. There is not enough evidence to base conclusions on regarding the mode of inheritance. The individual designated by an asterisk in the fifth generation is the young man described in the text. Solid black symbols indicate individuals both of whose hands showed the defect.

dividuals. His great-great grandmother was said to be stiff-fingered, although the joints involved could not be ascertained. In the family eight individuals were found whose hands showed bony ankylosis of interphalangeal joints. In each case the joint involved is the distal interphalanegal joint of the index finger. In six cases the index fingers of both hands are stiff; in the other two, the defect is limited to the right hand. Figure 2 indicates the distribution of the defect in the family.

The sister of the young man has bony ankylosis of the terminal interphalangeal joints of both index fingers. The condition is almost identical with that of her brother. A younger brother has normal fingers.

The mother has only one stiff finger, the index finger of the right hand. Again, only the terminal joint is affected. The condition, however, is not exactly the same as that exhibited in her children. The finger is of normal length and of normal size as far as the middle of the second phalanx where it tapers markedly and then expands somewhat at the end of the finger. The joint site is the narrowest part of the fused bones; no lateral prominences are present on the base of the terminal phalanx. Skiagraphs could not be obtained.

Five of the mother's first cousins show the condition; four in one family present it on both index fingers; one cousin in another family has a stiff index finger on the right hand. The mother's mother was free from the defect, as were also all other members of her generation. The young man and his sister are the only individuals in their generation who exhibit the condition. All affected individuals were born with the stiff joints.

These cases are particularly interesting inasmuch as the only joint involved is the one which is most rarely affected, namely the distal interphalangeal joint of the index finger. The hereditary nature of the defect is apparent. The condition is, in every instance, passed on through the female line. There is no history of the defect in any of the paternal lines. There are not sufficient cases to draw any conclusions concerning the exact mode of inheritance although it is evidently not caused by a dominant mendelian factor.

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✦

PARRAKEET GENETICS

VOEGEL FERNER LANDER is a quarterly journal, devoted to the interests of breeders of exotic birds.*

Part three of the present volume includes the continuation of an article by Helmut Hampe on color inheritance in the grass parakeet or bugerigar (*Melopsittacus undulatus*) which perhaps merits attention, since reports on the genetics of this animal have been restricted almost entirely to the pages of fanciers' journals. Hampe's article is based on the work of Duncker and follows his terminology in designating: (1) a dominant lipochrome factor, *F*, which permits the formation of yellow pigment; (2) an allelomorphic series of "oxidase-factors," O_n, O_g, O_w, in decreasing order of dominance, which determine different degrees of color intensity, both of the dorsal barring and of the blue on the breast, O_n being the most intense and O_w almost white. The intensity of the yellow pigmentation is apparently not affected by this factor. (3) A gene, *B*, which shifts the feather color toward the red. Recent work by Steiner indicates that the color modification produced by this factor is a structural effect. The loci of *F* and *B* are linked, with a cross-over value of about 15%.

Hampe's article is intended for the non-geneticist, and hence presents the material in elaborately simple, though accurate, form. Breeding data are not given, but footnotes refer the reader to Duncker's and Steiner's original papers, although there is no citation of one of Duncker's most interesting papers (*Vögel ferner Lander* 5 [1931] 91-96), in which he has reported a sex-difference in crossing over.

Other articles in this issue include brief notes, descriptive and practical, on several species of fanciers' birds, and a rather long discussion of the campaign against psittacosis, together with a transcript of the recent legislation in Germany designed to combat it.

The final number of volume eight is devoted entirely to a monograph on the true love-birds (Agapornidae), also by Helmut Hampe. The author describes in detail fourteen varieties, with some discussion of the history, habits, distribution, etc., of each type. Results of various intervarietal crosses are described incidentally in the course of the monograph, but there is no attempt at a systematic treatment of such genetic information as may be gleaned from these crosses. The paper is illustrated with several plates of excellent photographs in black and white.

PAUL R. DAVID
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*VÖGEL FERNER LANDER, edited by Eduard Schütze and W. Schinke, with the cooperation of Dr. H. Duncker. Band VIII. Friedr. Vieweg u. Sohn A. G., Braunschweig, 1934.

HYBRIDS OF WHEAT, RYE, AEGILOPS AND HAYNALDIA

A Series of 122 Intra- and Inter-Generic Hybrids Shows Wide Variations in Fertility

W. J. SANDO
U. S. Department of Agriculture

BECAUSE of recently stimulated interest in intra- and inter-generic hybridizations of Triticum, Secale, Aegilops, and Haynaldia, it is considered opportune to report an extensive group of hybrids made by the writer with these genera. Samples of these hybrids were exhibited at Ithaca, New York, from August 24 to August 31, 1932, during the sessions of the Sixth International Congress of Genetics. Since that time additional information has been obtained regarding the fertility of these hybrids. A list of the 122 hybrids is given at the end of the article in Table I. The heads of 32 of them are shown in Figures 3 and 4 in comparison with the parent forms.

Of the total number of F_1 hybrids produced from the above crosses only three are self-fertile, namely, *Aegilops longissima* × *Triticum polonicum*, *T. turgidum* × *H. villosum* and *Aeg. variabilis* × *Aeg. triuncialis* (*brachyathera*). The two former fertile hybrids produced only a few seeds when selfed and all of the forms obtained in subsequent generations are similar to the F_1 hybrids in their morphological characters but an increase over the F_1 hybrid in self-fertility resulted. The latter F_1 hybrid was fairly self-fertile and produced morphologically diverse forms in the second generation.

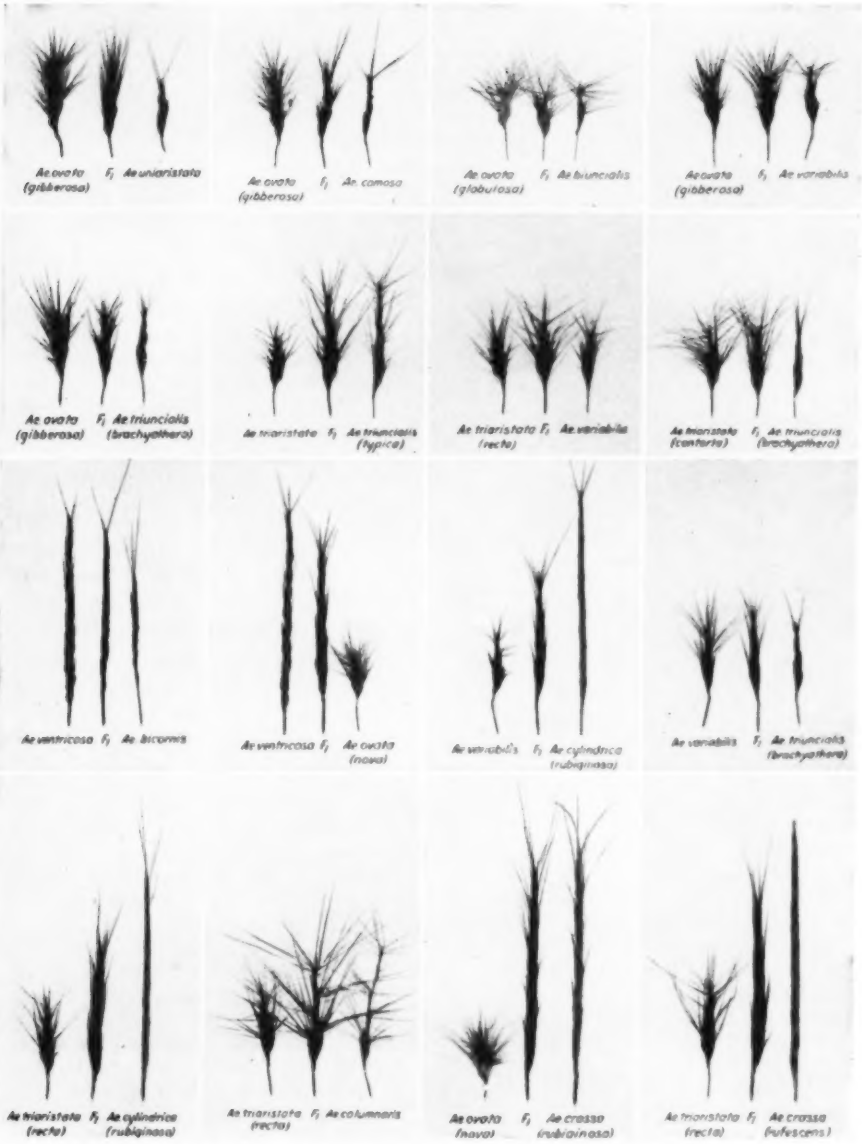
The writer's interest in inter- and intra-generic hybrids dates back to 1922 at which time the first hybrid was made. Since that time hundreds of hybrids have been produced. Morphological descriptions and results in crossing certain hybrids of Aegilops with Triticum and Secale have been reported[1,2]. Other hybrids of the same genera were studied cytologically.[3] Although not all of the species of Triticum, Secale, Aegilops, and Haynaldia have been available to the writer, the large number of species hybridized makes possible a presentation in Table I of the condensed results in the crossing of different species in various groups within a single genus as well as between the different genera.

Fertility of Emmer Group Hybrids

From the above it may be observed that the greatest number of fertile hybrids was produced by combining Aegilops and Haynaldia species with species of the emmer group of the genus Triticum. The anthers of these fertile F_1 plants were observed to dehisce weakly and only a few seeds were produced. Plants from later generations appear to be fully fertile and are similar morphologically to the F_1 hybrids.

The F_1 hybrid from a cross of a hexaploid species of the genus Triticum with a tetraploid species of Aegilops produced only a few seeds and in later generations was difficult to perpetuate because of sparse seed set and poor viability of the seed.

It is also of interest to note that with the exception of *T. timofeevi* all the species of the Emmer group of the genus Triticum having fourteen haploid chromosomes when crossed with one another produced hybrids that were fully self-fertile and showed normal segregation in the F_2. Species of the Emmer group when crossed with species of the Vulgare group showed partial fertility in the F_1 plants.


Ae ovata (gibberosa) F1 Ae uniaristata
Ae ovata (gibberosa) F1 Ae. comosa
Ae ovata (globulosa) F1 Ae biuncialis
Ae ovata (gibberosa) F1 Ae variabilis
Ae ovata (gibberosa) F1 Ae triuncialis (brachyathera)
Ae triaristata F1 Ae triuncialis (typica)
Ae triaristata (recta) F1 Ae variabilis
Ae triaristata (contorta) F1 Ae triuncialis (brachyathera)
Ae ventricosa F1 Ae bicornis
Ae ventricosa F1 Ae ovata (nova)
Ae variabilis F1 Ae cylindrica (rubiginosa)
Ae variabilis F1 Ae triuncialis (brachyathera)
Ae triaristata (recta) F1 Ae cylindrica (rubiginosa)
Ae triaristata (recta) F1 Ae columnaris
Ae ovata (nova) F1 Ae crassa (rubiginosa)
Ae triaristata (recta) F1 Ae crassa (rufescens)

THIRTY-TWO INTER-SPECIES AND INTER-GENUS HYBRIDS

Figures 3 and 4

The above illustration and that on the opposite page show form of head of thirty-two of the parents and hybrids discussed in the text. The parent forms are at the sides in each group with the F_1 in the center. The series furnishes a fascinating study in the expression of the various parental characteristics in the F_1 hybrid. It is easy to pick out examples of dominance, blending inheritance, hybrid vigor, and one case in which the F_1 is much smaller than either parent.

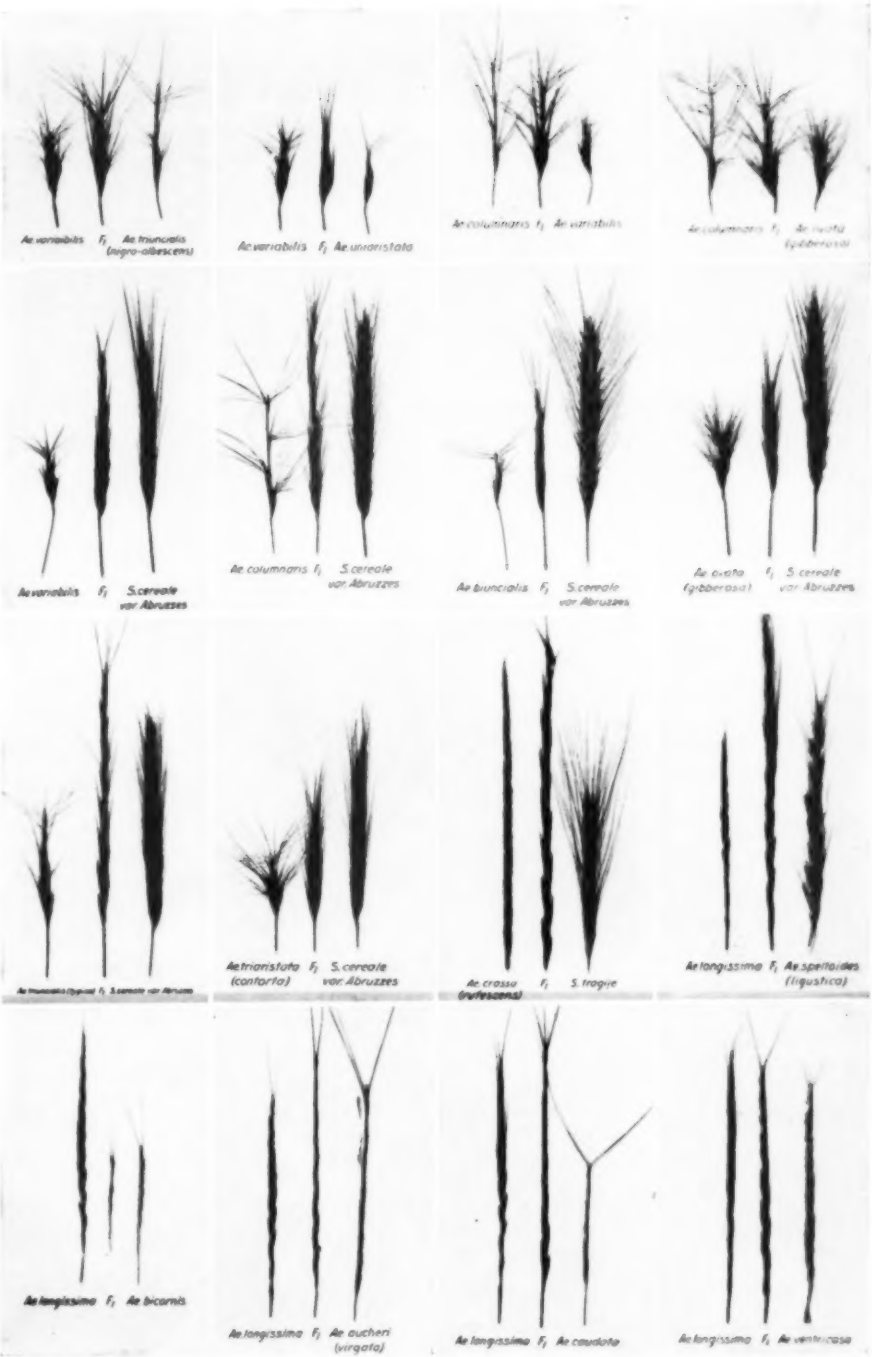

Ae.variabilis F1 Ae.triuncialis (nigro-albescens)
Ae.variabilis F1 Ae.umbristata
Ae.columnaris F1 Ae.variabilis
Ae.columnaris F1 Ae.ovata (gibberosa)
Ae.variabilis F1 S.cereale var.Abruzzes
Ae.columnaris F1 S.cereale var.Abruzzes
Ae.biuncialis F1 S.cereale var.Abruzzes
Ae.ovata (gibberosa) F1 S.cereale var.Abruzzes
Ae.triaristata (cerfarta) F1 S.cereale var.Abruzzes
Ae.crassa (orfeocens) F1 S.tragia
Ae.longissima F1 Ae.speltoides (ligustica)
Ae.longissima F1 Ae.bicornis
Ae.longissima F1 Ae.aucheri (virgata)
Ae.longissima F1 Ae.caudata
Ae.longissima F1 Ae.ventricosa

Figure 4

The above results have not been observed to hold in the genus Aegilops. Practically all of the hybrids between the various species of Aegilops are fully self-sterile. Several tetraploid hybrids in Aegilops have been obtained. The triploid hybrids in Triticum obtained by the writer were all found to be self-sterile in the F_1 while several triploid hybrids of Aegilops with Triticum were partially self-fertile in the F_1 and almost fully self-fertile in later generations.

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Table I. List of intra- and inter-generic hybrids between the genera Triticum, Secale, Aegilops, and Haynaldia produced in the experiments reported in this article.

Female parent		Male parent
Triticum aegilopoides	n	Haynaldia villosum
" dicoccoides	n	"
" dicoccum, var. Khapli	n	"
" durum, var. Kubanka	n	"
" polonicum, C.I. 7498	n	"
" turgidum, var. Alaska	n	"
Aegilops longissima	n	Triticum aegilopoides
" "	n	monococcum, var. flavescens
" "	n	timofeevi
" "	n	dicoccoides, var. spontaneonigrum
" "	n	dicoccum, var. Khapli
" "	n	durum, var. Kindum
" "	n	turgidum, var. Alaska
" "	n	polonicum, var. C.I. 7070
" "	n	spelta, var. Alatrom
" "	n	compactum, var. Dale Gloria
" "	n	vulgare, var. Hitkany
" variabilis	n	dicoccoides, var. spontaneonigrum
" "	n	dicoccum, var. Khapli
" "	n	durum, var. Arnautka
" "	n	turgidum, var. Alaska
" "	n	polonicum
" "	n	spelta, var. Alatrom
" "	n	vulgare, var. Hitkany
" "	n	compactum, var. Dale Gloria
" columnaria	n	dicoccoides, var. spontaneonigrum
" "	n	dicoccum, var. Khapli
" "	n	turgidum, var. Alaska
" "	n	polonicum, var. C.I. 7070
" "	n	spelta, var. Alatrom
" "	n	compactum, var. Coppei
" "	n	vulgare, var. Hitkany
" triuncialis (typica)	n	timofeevi
" triuncialis (brachyathera)	n	compactum, var. Coppei
" "	n	spelta, var. Alatrom
" "	n	persicum, var. strictinum
" ovata (gibberosa)	n	persicum, var. fulginosum
" "	n	dicoccum, var. Khapli
" crassa (rufescens)	n	persicum, var. fulginosum
" biuncialis	n	dicoccoides, var. spontaneonigrum
" "	n	spelta, var. Alatrom
" "	n	vulgare, var. Velvet Chaff
" "	n	durum, var. Kubanka
" "	n	turgidum, var. Alaska
" "	n	dicoccum, var. Black Winter
" comosa	n	dicoccoides, var. spontaneonigrum
" variabilis	n	Secale cereale, var. Abruzzese
" columnaria	n	" " " " "
" triuncialis (typica)	n	" " " " "
" ovata (gibberosa)	n	" " " " "
" biuncialis	n	" " " " "
" triaristata (contorta)	n	" " " " "
" crassa (rufescens)	n	" " " " "
" longissima	n	Aegilops speltoides (ligustica)
" "	n	" ventricosa
" "	n	" biuncialis
" "	n	" comosa
" "	n	" aucheri (virgata)
" "	n	" bicornis
" "	n	" ovata (gibberosa)
" "	n	" crassa (rufescens)

Female parent		Male parent
Aegilops longissima	n	Aegilops comosa
" "	n	" cylindrica (rubiginosa)
" variabilis	n	" triuncialis (brachyathera)
" "	n	" cylindrica (rubiginosa)
" "	n	" triuncialis (nigro-albescens)
" columnaria	n	" uniaristata
" "	n	" variabilis
" "	n	" ovata (gibberosa)
" "	n	" cylindrica (rubiginosa)
" "	n	" speltoides (ligustica)
" "	n	" aucheri (virgata)
" "	n	" crassa (rufescens)
" triuncialis (typica)	n	" ventricosa
" "	n	" cylindrica (ferruginea)
" "	n	" ovata (gibberosa)
" "	n	" triuncialis (brachyathera)
" "	n	" columnaria
" "	n	" aucheri (virgata)
" "	n	" biuncialis
" ovata (gibberosa)	n	" uniaristata
" "	n	" variabilis
" "	n	" comosa
" "	n	" triuncialis (brachyathera)
" "	n	" columnaria
" "	n	" ventricosa
" "	n	" crassa (rufescens)
" "	n	" biuncialis
" crassa (rufescens)	n	" aucheri (virgata)
" "	n	" comosa
" "	n	" cylindrica
" "	n	" variabilis
" "	n	" comosa
" "	n	" uniaristata
" "	n	" columnaria
" biuncialis	n	" triuncialis (brachyathera)
" "	n	" triuncialis (typica)
" "	n	" crassa (rufescens)
" "	n	" columnaria
" "	n	" aucheri (virgata)
" cylindrica (rubiginosa)	n	" ovata (globulosa)
" "	n	" crassa (rubiginosa)
" "	n	" columnaria
" "	n	" triuncialis (brachyathera)
" "	n	" " (nigro-albescens)
" "	n	" " (brachyathera)
" caudata (polyathera)	n	" ovata (gibberosa)
" "	n	" uniaristata
" comosa	n	" ovata (nova)
" ventricosa	n	" bicornis
" triaristata (contorta)	n	" triuncialis (brachyathera)
" "	n	" " (typica)
" " (recta)	n	" cylindrica (rubiginosa)
" "	n	" columnaria
" "	n	" crassa (rufescens)
" "	n	" variabilis
" bicornis	n	Haynaldia villosum
" ventricosa	n	" "
" ovata (nova)	n	" "
Secale fragile	n	" "
" "	n	Secale cereale, var. Abruzzese
Triticum dicoccoides	n	Triticum aegilopoides

Table II. Results of crosses of different species in various chromosome groups within a single genus and between the different genera.

Group and haploid chromosome number	×	Group and haploid chromosome number	Fertility of F_1 plants
Elnkorn-7*	n	Elnkorn-7	fully self fertile
Elnkorn-7	n	Emmer-14	fully self sterile
Elnkorn-7	n	Vulgare-21	fully self sterile
Elnkorn-7	n	Aegilops-7	fully self sterile
Elnkorn-7	n	Aegilops-14	fully self sterile
Elnkorn-7	n	Aegilops-21	fully self sterile
Elnkorn-7	n	Secale-7	not yet produced
Elnkorn-7	n	Haynaldia-7	fully self sterile
Emmer-14	n	Emmer-14	fully self fertile
Emmer-14	n	Vulgare-21	partly self fertile
Emmer-14	n	Aegilops-7	8 partly self fertile others fully self sterile
Emmer-14	n	Aegilops-14	some partly self fertile others fully self sterile
Emmer-14	n	Aegilops-21	1 partly self fertile others fully self sterile
Emmer-14	n	Secale-7	fully self sterile
Emmer-14	n	Haynaldia-7	1 partly self fertile others fully self sterile
Vulgare-21	n	Vulgare-21	fully self fertile
Vulgare-21	n	Aegilops-7	fully self sterile
Vulgare-21	n	Aegilops-14	fully self sterile
Vulgare-21	n	Aegilops-21	fully self sterile
Vulgare-21	n	Secale-7	fully self sterile
Vulgare-21	n	Haynaldia-7	not yet produced
Aegilops-7	n	Aegilops-7	fully self sterile
Aegilops-7	n	Aegilops-14	fully self sterile
Aegilops-7	n	Aegilops-21	fully self sterile
Aegilops-7	n	Secale-7	not yet produced
Aegilops-14	n	Aegilops-14	8 partly self fertile others fully self sterile
Aegilops-14	n	Aegilops-21	fully self sterile
Aegilops-14	n	Secale-7	fully self sterile
Aegilops-14	n	Haynaldia-7	fully self sterile
Aegilops-21	n	Aegilops-21	not yet produced
Aegilops-21	n	Secale-7	fully self sterile
Aegilops-21	n	Haynaldia-7	not yet produced
Secale-7	n	Secale-7	inter-fertile
Secale-7	n	Haynaldia-7	fully self sterile

* Haploid chromosome number.

THE OLDEST PEDIGREE CHART

A Genealogical Table of the Horse and Pictures of Horsemen Dating Back 5,000 Years

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RECENT advances in our knowledge of the early history of domestic animals have brought to light many facts of interest not only to archaeologists, ethnologists, and historians but also having implications of direct importance to geneticists and to practical breeders of domestic animals. It may seem a little far fetched to allege that these researches extending back into remote antiquity have any practical implications, but it is the conviction of the author that some of the discoveries which are being made regarding animal husbandry at this remote period have a direct bearing on modern breeding problems as well as offering much of intellectual interest to students in this field.

One of the most important bearings of such studies is the light they throw on the length of time that animals have been domesticated. It is clear that man and the horse have been intimately associated for a very long time. During this period certain characteristics of the horse have varied while others have remained fixed. It is the belief of the author that enough evidence may be obtained of the early history of the horse to make possible conclusions as to which characteristics of the species have remained fixed over a period of 5000 years and which characteristics have showed marked variation. It is not unreasonable to assume that the characters remaining fixed over so long a period will be those that cannot readily be altered by selective breeding methods. If this thesis is sound, practical breeding gains thereby an added effectiveness and the science of genetics in its most general sense is able to extend the field of its observations not only in a horizontal direction, which would include the forms studied in laboratories and existing in nature at the present time, but also to begin to attain a "time dimension" which will enable us to reach more exact conclusions than are now possible regarding the original wild forms of existing domesticated animals. Such considerations and practical applications have recently, especially in plant genetics, led to important advances. However, in animal breeding, also, research has thrown some light on the original forms from which domestic breeds have sprung (for example, in breeding of English pure blooded horses, pigs, and Merino sheep), but in general the knowledge of the ancestry of domestic breeds is still rather fragmentary.

These introductory remarks will I hope indicate why the writer, an animal geneticist, has turned his attention intensively to archaeological explorations which are calculated to throw light on the methods of breeding practised as much as fifty centuries ago.

Archaeological Discoveries Regarding the Horse

The period following the World War has seen many remarkable discoveries in archaeology. Even Egypt, where intensive exploration has longest been in progress, has yielded such astonishing finds as the tomb of King Tutankamen. The plains of Mesopotamia and deserts of Central Asia have all yielded important secrets regarding human activity from thirty-five to fifty centuries ago. Amongst the numerous expeditions of this time there have been American, German, English, French, and Russian explorations which have secured very valuable information in

respect to the early history of the domestic horse. This material has come mainly from Central and Southern Asia and from Asia Minor, with a somewhat isolated region in Siberia also furnishing new facts of the utmost importance. The names connected with these researches have been mainly those of C. L. Woolley of London, Francfort of Chicago, de Mecquenem, V. Scheil, and Parrot of Paris, Unger, Hinrichs, and Freiherr von Oppenheim of Germany. The expeditions of the Russian Museum in Leningrad in the Altai, headed by Griasnow and that in the districts of Minussinsk, under the leadership of Teplouchow have also yielded important results.

The writer has set himself the problem of ascertaining by comparative study of archaeological material the probable origin of the present day type of domesticated horse, and to find as exactly as is now possible the cradle of domestication of this animal and the original form which was first domesticated. The researches of Antonius, Adametz, Nehring, Frank, Salensky, and Tschersky were taken as the starting point of the author's investigation. It is generally agreed by competent authorities, (among them W. Schmidt, W. Koppers of Vienna, Gahs of Zagreb and the prehistorian Oswald Menghin) that western Siberia is the most likely region in which to look for traces of the original domestication of the horse. It is the belief of these authorities that the domestication of the horse followed an earlier domestication of dogs and reindeer in this region. The writer began his studies in 1926 and visited in that year a large area in European Russia and the Caucasus. (He had at that time no knowledge of the discoveries of the above mentioned scientists as most of these works had not yet been published.) In the following year the author continued his explorations in the district of the Volga River and the Transcaucasus. In 1929 and 1930 further explorations were made in Siberia, Altai and central Asia. From there he returned with a great mass of new facts. In the meantime the successful excavations in Southern Asia had been under way and there also much important information had been uncovered.

The Horse in 3000 B.C.

Some of the most important discoveries of this period were those of C. L. Woolley regarding the early civilization of the Caldeans. Among the material brought to light in Woolley's excavations was a wonderful amber statuette of a horse which was found in the tomb of Queen Schub-Ad in Ur. This dated to early Sumeric time, about the fourth Millenium B.C. Furthermore on the famous standard of the kings of Ur there are pictures of real horses drawing war carriages. These unquestionable evidence of existence of domesticated horses at least 5000 years ago are among the earliest records we have. Furthermore it is clear that at this time the horse was by no means a new element in human economy. Woolley states that the houses of Ur are rounded off at the corners to facilitate the passage of the heavily loaded pack horses and donkeys in the narrow streets. From this it may be assumed that the people of fifty centuries ago were even then struggling with a traffic problem! Furthermore the horse had been present long enough to effect another architectural adaptation in the design of the steps of some of the houses which were built to make their use by riding horses possible. Pictures of hitched horses from Mari in the upper Euphrates valley show that Sumerian horses were used with a snaffle bit and not with a halter (cavesson). This discovery, which is reported by Dr. André Parrot, also belongs to the early Sumerian period about the beginning of the third Millenium B.C.

Evidence that the horse was at that time progressing from Central Asia toward the West may be found in the fact that in Asia Minor at Kultepe the horse first appeared about 2200 B.C. Before this time no evidence of the ex-

A HORSEMAN OF FIFTY CENTURIES AGO

Figure 5

This figure of a horseman engraved on a piece of bone shows that in the eastern Mesopotamian valley the horse had been domesticated and was being ridden at the time this object was made. In the region where this was found the horse had been long enough under domestication to effect at least two architectural changes in house design to accommodate equine traffic. In the fifty centuries which have elapsed since that time certain characteristics of the horse have remained fixed while others have been greatly altered by human selection.

istence of the horse has been unearthed.

On the other hand, in excavations of districts to the east of Ur—in Elam—discoveries of the greatest moment have been made. The French explorer de Mecquenem discovered in the layer between Susa I and Susa II some utensils carved from bone of which one piece is of tremendous importance. This fragment was located in a layer which, on the basis of careful archæological research has been fairly accurately dated, and this places this object as having a date not older than 2800 B. C. The fragment in question is an engraved picture of a horse which represents the oldest image of this animal known to the history of human culture. It is on a piece of bone and shows a slender horse with a noble, shapely head and short ears. The bushy tail is clearly in evidence. The proportions of neck, rump, length of leg and all other dimensions leave no doubt whatever that this figure represents a horse. On the back of the horse a man is seated drawn in bold lines. Similar drawings showing a man with a standing dog lead to the convincing conclusion that in this case a horseman is pictured which proves without doubt that riding was already an established art in this ancient civilization of Elam. In my opinion it is of no importance whether this picture represents a symbol, a hunting scene, or a mystical sign. I mention this fact especially because Professor E. Unger has raised the question in a letter to me whether this drawing is an actual representation of an existing fact (that is, a portrait) or only a symbol. The drawing in question is shown in Figure 5 and in the opinion of the writer this is one of the most significant evidences we have of the early history of the horse.

De Mecquenem is also to be credited with discovery of another very important piece of evidence concerning the early history of the horse. This is a matter of especial interest to horse breeders and geneticists because it deals with the subject of horse breeding in old Elam and in the southwestern highlands of Persia. The object in question (known as "seal 105F") is an engraved fragment showing a number of horse-heads arranged in a peculiar and very interesting manner. According to V. Scheil this seal in association with the as yet unexplained signs accompanying it, is an enumeration of horses. If, however, we examine this seal (Figure 6) we discern the following significant facts:

1. The horse-heads are situated in four horizontal rows.

2. The horses are of three categories as regards their manes: upright manes, pendant manes, and without manes.

3. If we examine the location of these three types we find that the three cate-

gories have a symmetrical arrangement with reference to the main diagonal.

4. It is remarkable that all the heads with pendant manes have a special symbol to the right of them. See the upper row. The head to the extreme right has by it a symbol which resembles a barred window. In the second row the same, at the left. In the third row the middle head from the left has by it a sign of three teeth on the smaller side of the rectangle. Beneath this four teeth. Note in the fourth row, first head on the left, a sign which today is universally used in biology to indicate "female." In this latter case it is remarkable that the symbol is engraved upside down. In the same row the third head from the center is accompanied by a sign which could easily be held to be a carriage with two horses.

5. The heads with upright manes in my opinion represent wild stallions, those with pendant manes, tame animals and those without manes, mares.

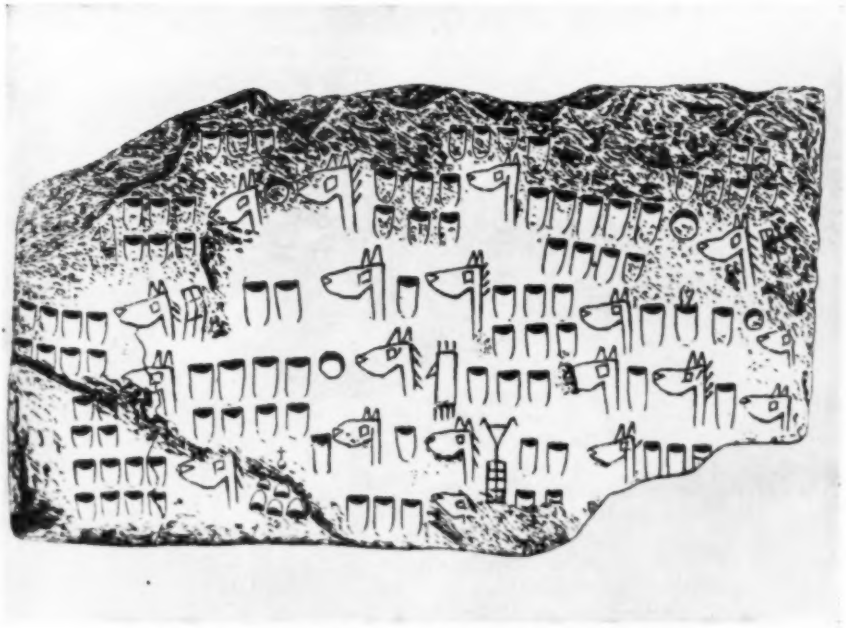
6. It is held by Professor Scheil that the maneless heads are those of colts. That this is not the case is proved to my satisfaction by the fact that some of the maneless heads as the first in the top row and the second in the second row and the third in the third row are pictured of far too coarse and too powerful a build to be mistaken for colts. (The diagonal arrangement of the heads may be also worthy of note). On the other hand we discover in contrast that some very delicate heads such as the fourth in the first row and the fourth in the third row are definitely maned. There are manes of different character, pendant and upright.

An analysis of the head forms is very significant to modern hippology. We can note the following facts:

a. A definitely ramlike profile of head (head 1, row 1).
b. A ramlike profile only in the nose region (head 2, row 1; heads 2 and 3, row 3).
c. Perfectly straight profile (all heads of row 2).
d. Concave profile of Arabian type combined with graceful slender head (third and fourth head, row 1; fourth head, row 3; fourth head, row 4).
e. In addition to these definite differences of the profile line the size of head in respect of the entire length and depth is interesting:
   Long and deep (head 2, row 2).
   Medium long and deep (head 2, row 4).
   Short and deep (head 2 and 3), row 4).
   Long and slender (head 3, row 1). Connected with Arabian profile.
   Medium long and slender (head 4, row 3).

All the above mentioned differences are regarded not as merely accidental differences of a mechanical or conventional nature but as studied reproductions of differences actually observed in the living animal. The head forms represented in this ancient seal are of types that today may be observed in the different races of horses. I need only note the existence in the Kladruber breed of a strongly ram profile and in the Arabian horse of a concave, fine cut head to demonstrate that the differences recorded five thousand years ago in Elam exist still today. Intermediate shapes can also easily be found.

Furthermore these characteristics are familiar to the practical breeder and are known to be definitely hereditary. The dominant inheritance of some of these characteristics is so strong that they are recognized as "prepotent" in inheritance as type of head has been observed to be and passed on for many generations. These head types are undoubtedly inherited as mendelian characters in the horse in nature. Any one of these forms may become typical of a few animals, of families, or of a whole stable or artificial race through the agency of human selection. It is a matter of no little interest to breeders and geneticists that on this seal from Susa, whose age must be fully fifty centuries, are shown all the profile types of horses existing today.



POSSIBLY THE OLDEST PEDIGREE IN EXISTENCE

Figure 6

This engraved seal from an excavation to the East of Ur in Mesopotamia is about 5000 years old. In the accompanying article the reasons are given for considering it to be a pedigree record. If this view is correct it represents the oldest pedigree of animal breeding of which we have knowledge. Note that the horse heads are arranged in horizontal rows and that there are three mane types (erect, pendant, and maneless) and three profile types (convex, straight, and concave). It is believed that the mane types represent some form of classification. The three profile types exist today. The symbols accompanying the horse heads are a matter of conjecture. Note the sign universally used today to denote "female" in the lower left quadrant of the seal.

This ancient Elamitic testimony regarding the horses existing at that time permits the conclusion that in Elam several original types and races of horses were then used. The horse heads are reproduced with wide, thick and plump, or with fine and aristocratic lines. There is no other alternative open than to classify the thick-set type with the Przewalsky horse (*Equus przewalsky* Poljakoff), and the slender form with the Tarpan (*Equus gmelini* Antonius). It is the considered opinion of the author that the early, heavy type of horse of western Europe is to be traced as a direct descendant of the Przewalsky type of wild horse. The heavy Persian horses are not to be considered as importations from Europe in prehistoric times but are the result of breeding native central Asiatic stock, which reached Iran with the Turanian invasions at an early time. The antiquity of this arrival of the horse cannot be determined but must have been very great. The more aristocratic type of horse was native in the highlands of Iran and the plains of northern Central Asia.

The early Sumerian and Elamitic civilizations, according to unequivocal testimony which is today available, knew and used the horse. It is the opinion of the author that "seal 105F" which has been discussed above is not as Scheil believes, an enumeration of

horses but is a genealogical table of individual horses used for breeding in an old Elamitic stable. If this view is correct, and I believe that any breeder of animals will admit the high probability that this is so, this discovery is the oldest known genealogical table known at the present time.

Not only were horses known and was selective breeding practiced in Elam, but in Sumeria donkeys were also known and mules were produced by cross breeding. Recently André Parrot of Paris has brought to light a picture of a horse hitched with a bridle from Mari in the central part of the Euphrates valley. While the donkey was known in Sumeria, no traces of it appear at Elam. This animal was introduced into Mesopotamia by old Semitic tribes of western Asia or Arabia. The first cross breeding of the horse and the donkey probably took place at Ur where mules were known to have been in use. With the disappearance of the early Sumerians and the replacement of their civilization by the Akkadian the horse vanishes from the history of this region. Following this is a period of about one thousand years which represents a complete hiatus in the history of the horse in this region. After this strange gap the horse again reappeared and may be traced to modern times.

As far as we can summarize the situation at the present time the horse came from the north and entered the Mediterranean valley from the east. Its migration can be traced as follows: from Siberia to Turkestan and then to the regions now known as Persia (Iran, Elam). From the highlands of Persia the horse then penetrated to Sumeria (Ur) in the southern Mesopotamian valley. Thence the horse extended upwards through Mesopotamia, reaching Mari (Abu Kemal) near the border of Syria and to the region of Irak in middle Mesopotamia. Shortly before 3000 B. C. the horse disappeared from the lower Mesopotamian valley and no record of it can be found again until about 200 B. C. This time the horse entered the valley from the west. From the earliest times the horse is to be found uninterruptedly among the tribes on the border of Iran and their neighbors.

In the region where these discoveries were made, vast areas have not yet been subjected to intensive archæological study. When we consider the very significant facts it has been possible to deduce from these rather scanty relics of the early history of the horse that have thus far been brought to light, there would appear to be no question that archæological researches into the history of domestic animals may have practical implications of great importance in addition to the purely intellectual satisfactions of such researches.

✦

The First Step to Success

AN interesting testimony to the importance of the selection of the proper parents by a child who desires to be successful is to be found in some remarks attributed to the late Adolph Ochs, publisher of the *New York Times*. Mr. Ochs was of the opinion that a company to assure success could be profitably undertaken, if the following simple requirements regarding policy holders were adopted:

My Company to Assure Success would ask of its policy holders nothing out of the ordinary, no special brilliance, no abnormal talents, no inordinate industry even. In passing upon applicants for success it would, however, inquire rather carefully into a youth's antecedents and parents, for the first thing is to be well-born.

Satisfied on this point, the company would investigate the youth's record to date and if he was found to have done moderately well at school, if he had established a reasonably good reputation in character, and if he possessed good health—good health is essential, then he would be eligible.

In issuing this policy about all the rules and conditions would be: You must strive faithfully to live up to the precepts taught you as a child by your mother. You must be industrious, temperate and honest. You must give diligent attention to your business, lead a clean, honorable life and deserve as well as to try to succeed.

EARLY EMBRYOLOGY OF DROSOPHILA

The Mechanics of Gastrulation and Its Relationship to Gynandromorphs Found In Drosophila Melanogaster

HAL B. PARKS
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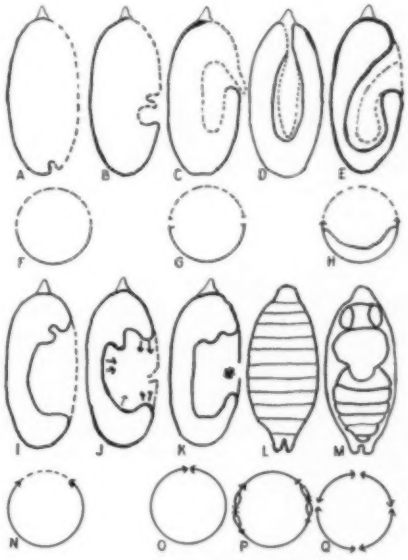
IN most literature dealing with the relationship of gynandromorphic nuclear distribution in the developing embryo of *Drosophila melanogaster*, little emphasis has been placed on the distribution of cleavage nuclei in normal embryos from the earliest cleavage stage through gastrulation. Morgan and Bridges* suggested that some one should work out the complete embryology of *Drosophila melanogaster* in order that definite information concerning cleavage patterns and the process of gastrulation would be available. The writer has worked on this problem for the last three years and presents here a brief summary of the mechanics of gastrulation and its relationship to gynandromorphic patterns in advance of the publication of the unabridged thesis.

It is obvious that the ectoderm and the amnio-serosa are the only tissues which can be considered due to the fact that the genetic markers by which the gynandromorphic parts can be distinguished are derived from the hypoderm which is ectodermal in origin. The question involving the amnio-serosa concerns itself with Morgan's* original query as to what becomes of this tissue and as to what part it may have in the formation of the ectoderm.

The drawings (Figure 7) show the mechanics of gastrulation as related to the formation of the amnio-serosa, its disappearance and the formation of the dorsum of the larva from the ventral lateral ectodermal cells. In all cases the heavy line of the diagrams represents the ventral part of the blastoderm and the dotted line the amnio-serosa. In this drawing *A-D* illustrates the folding over of the embryonic tail by the rapid growth of ventral blastodermic cells dorsally and anteriorly. The dorsal blastodermic cells are converted into the amnio-serosa. Diagrammatic cross-sections illustrating the above relationship are shown in *F-G*. Where the tail begins to unfold, the amnio-serosa is apparently made up of two parts (*E*). *H* is a cross-section show-



EARLY DEVELOPMENT OF DROSOPHILA LARVA

Figure 7

The drawing shows the mechanics of the formation gastrula of the early embryo. For detail see text. It is shown that the ventral portion of the embryo which shows the gynandromorphic characteristics is derived from tissue originally arising in the dorsal region.

*MORGAN, T. H. AND C. B. BRIDGES: The Origin of Gynandromorphs. Carnegie Institute of Washington *Pub. No. 278*, pp. 1-22, 1919.

ing the ventral plate thickened. *I, J* and *K* illustrate the disappearance of the amnio-serosa and the upgrowth of the lateral ectodermal cells. This process is well illustrated by two cross sections, *N*, where the ventral material is extending dorsally, and *O*, in which the entire dorsum is covered.

Soon after the stages pictured in *K* and *O* are completed, the larva emerges. The larval period is of about eighty hours duration. It is during this period that the imaginal discs are formed. *L* and *P* are diagrammatic drawings of about the time the larva goes into pupation; *P* is a cross-section of the abdomen, showing the imaginal discs formed at the mid-lateral line. *M* is a diagram of the young adult, a cross-section of which (*Q*) shows the paths of growth of the cells from the imaginal discs. There are four imaginal discs to the segment, two dorsal and two ventral making a total of about forty-three discs in the entire animal. Counts on the number of cells making up individual imaginal discs tend to indicate that about seventeen are present when the discs are first visible through the microscope.

It must be recalled from the above discussion that the entire hypoderm of the larva is of ventral origin hence the imaginal discs are of ventral ectodermal origin. It follows, therefore, that the final chitinous exoskeleton which covers the adult and contains the gynandromorphic genetic markers is of ventral origin.

With these facts in view several conclusions can be drawn:

1. The amnio-serosa has no relationship to the future mosaic pattern, as this tissue is eliminated and is so situated that the imaginal discs when formed are not in the area of elimination as they are ventral and lateral to it.

2. The gynandromorphic pattern must depend on the pattern found in the imaginal discs as these form the chiton on which the genetic markers express themselves.

3. This pattern was originally laid down in the ventral plate.

4. The process of gastrulation presents difficulties in the tracing of cell-lineage in gynandromorphs as the dorsal side of the embryo is formed from ventral cells and because the imaginal discs originate from minute areas along the median lateral sides.

✣

THE CONSTITUTION CULT

A GLANCE at any index of medical literature which includes the publications for the past ten years will reveal the recent swing of interest toward the constitution, as it is understood biologically, and its importance in special problems of health and disease. Anthropologists, geneticists, biometricians, and psychologists as well as medical specialists have made investigations into the various aspects of the subject and the results of their labors reveal a certain, but comparatively modest, amount of scientific progress. As a natural derivative from the more scientific aspects of these studies on the constitution, the public has by and large become "constitution conscious" and with the ever ready aid of the physical health cults (to which some physicians subscribe), are busying themselves more and more with attempts to improve their bodies and fortify them against the ravages of fatigue and disease, and thus to attain a maximum of health.

The author of "The Constitution and Its Reaction in Health"* presents first an analytic approach to the constitution and then the factors which tend to modify it. He contrasts the "1850 type" of attitude toward the size of

*Hammond, T. E., *The Constitution and Its Reaction in Health*. pp. 160. London H. K. Lewis & Co. 1934.

families, luxury, holidays, work, games, health, exercise, food, weather, etc., with that of the pre-war generation toward these factors, and finally with the present generation:

> The whole outlook of life has been changed. The object of life now seems to be to cultivate physique and health, so that life may be enjoyed and the instincts satisfied. Worship of the sun, of the open air, of bathing and of games has become the object of life. In an age of activity these people would be looked upon as idlers and loungers. It is true that similar rites were practiced by the Greeks and Romans, but only in the intervals of strenuous effort, as a relaxation from work. They were never cultivated as the aim of living as is the case today.

The book contains twenty-two short chapters, among which are those dealing with such topics as rules of health, fresh air, the sun, exercise, bathing, food, rest, cultivation of the mind, etc. wherein the author expresses some serious doubts as to the efficacy of certain popular customs and recommendations in creating and maintaining a healthy mind and body. He is evidently not in favor of radical "health" seeking plans, which may, for all that is known, produce more strain and handicap than benefit:

> Many who are advocating their value are young people under 30. They have not yet lived through those years when the strain of living is first felt, nor have they yet been up against life. They seem to forget that when a man has healthy parents, and when the home and food are good, health should always follow. People of their class always enjoyed this without seeking or cultivating it. * * * * I have come to the view that this so-called cultivation of health will eventually be found a big drain upon the nervous system. As they grow older, many of those who practice it will crack up when called upon to face any strain. * * * * Few of the great athletes I have known have stayed the course of life, unless they have compensated for their early activities by later taking things extremely quietly. When they have some illness they quickly go under. * * * * For whilst fresh air, sunlight and exercise have undoubtedly some beneficial action, in excess they may be harmful to many.

Many aspects of the constitution are discussed including its reactions during the different life stages, the constitutional reactions to various types of therapy, the influence of season and weather, and the contrasting general qualities of the hyposthenic and hypersthenic types of body structure and function. Some sound advice is given for the physically ill, the neurotic, and the convalescent. He opines that much of the prevailing ill health is due to the great strain on the nervous system resulting from the fads and fashions that have appeared in recent years. The break with tradition has been too great and "we have forgotten how to live." The book is informative and entertainingly written.

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◆

GENETICS OF ZEA MAYS

ONE might, in reviewing this long-awaited monograph,* dismiss it with but a single minor criticism. The title is misleading. It should have been called "Catalog of Mendelian Characters in Maize," for it is, indeed, a complete and well arranged inventory and description of the heritable characters of maize. This, as any maize geneticist will testify, is, in itself, no mean task. Dr. Eyster, who has probably discovered and studied more different characters in maize than any other geneticist, has handled it with ability and has succeeded in producing a volume of some 200 pages that will be indispensable to every maize geneticist and useful to many others. True, there is an occasional departure from the rigid impartiality which the reader has a right to expect in a publication of this type, but these lapses are not frequent and, for the most part, not serious. Also, the illustrations, of which there are 91, would have been considerably improved had the author made use of more of the excellent photographs which have appeared in the JOURNAL OF

*EYSTER, WILLIAM H., *Genetics of Zea Mays.* Reprint from *Bibliographia Genetica,* XI. Martinus Nijhoff, The Hague. 1934. (For sale by the author, price $1.50.)

HEREDITY in preference to new photographs of his own. It is regrettable, too, that the linkage maps in this monograph differ in so many details from those compiled by Dr. R. A. Emerson, a situation which can only result in needless confusion.

Unfortunately, however, the monograph is not called "Catalog of Mendelian Characters in Maize" but is very definitely entitled *Genetics of Zea Mays*. On those grounds it is subject to criticism of a more serious nature. Such a title brings to mind a picture of an imposing edifice still, of course, in the early stages of construction and not so magnificent, perhaps, as the *Genetics of Drosophila*, yet quite a sizable structure, already exhibiting in outline some rather striking and original features and showing, here and there, the touches of some really brilliant architects and craftsmen. Instead, we are presented in this monograph, for the most part, with a series of pictures of the bricks and stones and tools that have been utilized in the erection of the building, with no suggestion of the growing splendor of the structure.

But to abandon the metaphor and be specific, the volume contains not a single word on the monumental work of Shull, East, Hayes and Jones on the effects of inbreeding and crossbreeding, work which not only led to the solution of these perplexing problems, except in the minds of a few reactionaries, but also brought about a widespread revision in methods of plant and animal improvement. No mention is made of Richey's ingenious experiments on convergent improvement which also have a bearing on this subject. Not a line on East's and Emerson's early work on quantitative inheritance which contributed to the establishment of the multiple factor theory. Not a line on the experiments of Collins, Kempton, Emerson, Longley, Randolph, Mangelsdorf, Reeves, and Beadle on genetics and cytology of species hybrids with Zea. Some of this work, such as Emerson's and Beadle's studies of crossing over between Zea and Euchlaena chromosomes, represents a marked step forward in methods of attack on the species problem. Not a line about Lindstrom's interesting studies on linkage of qualitative and quantitative characters, or Brink's extensive experiments on the dynamics of the waxy gene, a notable attempt at focusing chemistry and genetics on the same problem. Stadler's brilliant and ingenious experiments on natural mutations are ignored while his work on X-rays, which ranks with Muller's in opening a new era in genetic investigations, is dismissed with a page, about one-fourth of which is devoted to a subtle implication that Stadler's experiments were not properly controlled. The brilliant cytogenetic studies of Miss McClintock and her associates are treated all too briefly and with too little appreciation of their real significance.

These are some of the serious omissions that come to mind in reading over the monograph. Others could no doubt be mentioned but these will suffice. I think, to show that a thorough winnowing has taken place, the wheat has been separated from the chaff and then, by some tragic error, much of the wheat has been thrown away.

It cannot be said that these contributions were omitted for the sake of brevity because the author has found space to devote seven pages to a description of experimental technique, including in this section such minutiae as the statement that the pedigree is written on a No. 42-B Dennison's Marking String Tag. Surely no one would argue that these contributions which I mention are not an essential part of the genetics of maize. The author himself admits that they are when he includes references to most of them in his Section IX on "Literature on the Genetics of Zea Mays," which, incidentally, is reasonably complete and is one of the most valuable parts of the monograph.

We can only assume, I think, that the author set out to compile nothing more than an inventory of the heritable

characters of maize, leaving the real story of the genetics of maize still to be written. In which case, as I have already indicated, there is only one criticism to be made; the monograph has the wrong title.

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✦

BREEDING FARM ANIMALS

BOOKS on the breeding of farm animals which attempt to cover the entire field of zoological relationships, physiology of reproduction, genetics, and the art of breeding are of necessity largely compilations drawn from many sources. If the author has been active in one of the fields, it is only natural that he should present this in considerable detail and with his own viewpoints well developed. This is well illustrated in the recent revision of Rice's text.* The chapter on selection has been enlarged from twenty pages to nearly one hundred. This covers most of the attempts at evaluating dairy sires by means of bull indexes and related topics, as they have been developed in the eight years elapsing between the editions. It is well written and offers a good starting point for study of the subject. The author is at his best in this portion of the work.

The section covering inbreeding and systems of breeding has been enlarged somewhat but still represents a relatively small portion of the work. Wright's coefficients of inbreeding and relationship are included in this edition.

A comprehensive discussion of the relationships of our farm animals to their wild cousins is a welcome addition to any book on this subject. This has been included in the introduction of this edition and is interestingly written. Unfortunately, there is at least one important error in this discussion, as well as an important omission from the outline of zoological classification of the mammals. No direct references are given for this portion of the book, but, in the preface the author states that he has drawn freely on the works of R. Lydekker on the higher mammals. In discussing the four groups of wild relatives of the domestic sheep, the bharal (*Ovis nahura*) is rightly given as standing intermediate between sheep and goat. However, one of the reasons given for this seems to be confused. The statement "[bharal] like the sheep have . . . . and lachrymal glands on the face" is apparently wrong. The presence or absence of these glands is one of the most important, if not the most important of the distinctions between the sheep and the goats. The common domestic sheep have the glands and the domestic goats lack them. Lydekker states in one of his works, "The Sheep and Its Cousins," that both the udad or Barbary sheep and the bharal or blue sheep of the inner Himalaya lack face glands. The following quotation from Beddard's work on mammals will show the importance of not confusing this point: "*Ovis nahura* is chiefly responsible for the impossibility of strictly separating the Sheep and Goats. It has no suborbital glands or lachrymal fossae, which are as a rule present in the Sheep and absent from the Goats." No mention is made of the relationship of the Musk Ox to the other members of the Bovidae. As this species is on the borderland between the sheep and the ox, it should have been included in the classification.

It would be too much to expect of a general text to approach a complete discussion of the physiology of reproduction, and the intimately related field

*RICE, VICTOR ARTHUR, *Breeding and Improvement of Farm Animals.* Pp. 516. Second edition, 1934. Price $4.00. The McGraw-Hill Book Company, New York.

of endocrinology. Two of the topics included were only touched on and in the reviewer's opinion are important enough that they should have received more attention. These are the artificial insemination of farm animals and the diagnosis of pregnancy. It would seem to be as relevant to include more details on the subject of artificial insemination as it is to give the detailed discussion of the clinical examination of bulls and cows for sterility which can only be done efficiently by certain highly skilled veterinarians. Pregnancy diagnosis is relegated to one short paragraph with no mention of the possibility of either biological or chemical tests. While it is true that it is not possible to apply the Aschheim-Zondek mouse test or the Friedman modification by the use of rabbits to the urine of our domestic animals in the same way as to human urine, the testing of mare urine by the estrin test as adapted by Crew, Miller and Anderson and the testing of mare serum by the technique of Hart and Cole seem to be proving useful. The chemical test of Cuboni for mare urine is still in the stage of trial, but holds promise.

The portion of the book covering theoretical genetics is drawn largely from the texts of Babcock and Clausen and of Sinnott and Dunn. Considering the size of strictly genetic texts, it would be unkind to criticize the author if his condensed treatment should seem somewhat sketchy. In view of the fact that this work is on farm animals, it seems pertinent to direct attention to the inadequacy of the discussion of the chromosomes of domestic animals. True, the information that is available is meager and may possibly need serious revision in the future. The only chromosome studies on farm animals discussed are those of Wodsedalek on the chromosomes of cattle. More recent work by Krallinger indicates that the diploid number is 60 instead of 37 as given by Wodsedalek. This may mean that the older technique was inadequate. The important works of Painter, Hance, Krallinger and Sokolov on the chromosomes of the horse, swine, cattle, sheep and goats are mostly recent and might at least have shared the two pages devoted to Wodsedalek's early paper on the chromosomes of cattle.

"Inheritance in Farm Animals" is treated in an appendix. We would expect this to be a complete cataloging of the attempts which have been made to discover or interpret the inheritance in our farm animals. If this scheme were not to be followed, we would expect a thorough digestion of all the work concerning these species. It is neither. Theory and fact are thrown together without much refinement. Much of the material is presented in the form of extended quotations. The list is not complete for any one of the five species. The omissions must not be due to the author's considering them unimportant, as he includes a number which might be so considered. He mentions the "Gromet" pattern in sheep, yet omits entirely the series of papers by Roberts and associates on color in sheep which include discussions of both "Badger-face" and "Reversed Badger-face," this latter probably being the same as the "Gromet" pattern. In some other cases the earlier and less complete discussions of the same work have been chosen. With the exception of work referring to cattle which comes the nearest to being complete, only four pieces of work are referred to which were published since 1925, two for goats, one for swine, and one for sheep. Some other works on these species published after 1925 have been referred to in the main text, but they are few. A perusal of any of the abstracting journals for the period from 1925 to 1934 would supply a long list which, in the review's opinion, includes an appreciable number of really important papers on inheritance in farm animals. Also some of the earlier papers on swine inheritance, as those of Detlefsen and Carmichael and of Spillman, seem important enough that they should merit discussion and separate mention.

Probably many of our criticisms resolve themselves about the fact that the text is written largely in terms of dairy cattle, and the other species are brought into the picture incidentally and sometimes almost as an afterthought. Yet if the book is to completely serve its purpose, it should be more evenly balanced in this respect. There are a few loose statements and minor errors scattered through the text. While we have attempted to point out the main defects of the text, it is realized that it is an apparent impossibility for one author adequately to cover in one volume such a wide range of subjects. The book is written in an easily readable style, and the author has, in this edition, indulged in many general statements and comments which are frequently of a philosophical nature. In the reviewer's opinion, this has made the book more attractive.

A text on this subject is presumably written primarily for use in college classes. With a well-informed teacher the book should serve its purpose. It would have a much more limited usefulness for the general reader. This is also true in the case of the student without preliminary courses in anatomy, physiology and genetics. If all the students had a good grounding in these subjects before using the text, about half of the material could be deleted. As long as the classes continue to have students with both kinds of training, it probably is necessary to include this. We leave these questions to those responsible for the teaching of courses in animal breeding.

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ORIGIN OF INDIVIDUAL DIFFERENCES

PROFESSOR Frank S. Freeman of Cornell University has presented in this volume* of three hundred fifty-five pages an extremely interesting and readable account of researches on the nature and causes of differences between human individuals in their emotional and intellectual capacities. He accepts Spearman's "two factor" theory of intelligence, which asserts that two elements are involved in all abilities, one a general factor which operates in every intellectual function, and one or more specific factors each of which activates a different mental faculty.

It is repeatedly asserted throughout the book that both hereditary and environmental agencies are responsible for the development of mental traits. With this the geneticist can heartily agree. Divergences from the author's views arise when he assesses the relative importance of these two categories of influences in specific cases. The pioneer Galton, though emphasizing heredity, recognized the importance of extrinsic factors in molding the individual. The author quite properly criticises those students in human heredity who urge that correlations between close relatives are measures of the strength of heredity, for as a matter of fact they are probably the results of the simultaneous action of genes and of a common more or less constant familial environment that has persisted from generation to generation and from one branch of a family to another. But the author is, I believe, in error when he maintains that the majority of men and women of ability will be produced by mediocre parentage. Miss Catherine M. Cox† showed that over eighty per cent of the fathers of 282 eminent men were of the nobility, professional men, semi-professionals, engaged in higher business, or were members of the gentry.

One of the most arresting sections of

*Freeman, Frank S., *Individual Differences.* 355 pp. Henry Holt and Co., New York, 1934.

†Cox, Catherine M., *Genetic Studies of Genius,* Vol. II, The Early Mental Traits of Three Hundred Geniuses. 842 pp. Stanford University Press, 1926.

the book is an abstract of Gordon's work on canal boat children of England. These youngsters, who live with their parents on canal boats, have almost no opportunities for formal education and dwell in an extremely meager intellectual environment. Gordon found that the intelligence quotient of these children even within the same family declined with advancing age, the correlation between intelligence and chronological age being —.75. The children from 4 to 6 years of age had an average intelligence quotient of 90. The older ones from 12 to 22 years old presented an intelligence quotient of only 60. These facts suggest that in the absence of such stimulation as formal education and its correlatives provide, mental development does not progress at a normal rate. Perhaps, as Freeman suggests, the Binet Test is inadequate for measuring intelligence in people who have not had formal schooling. In other words, there may be innate mental development which cannot be detected by a test designed for school children

The existence of differences in mental performance as between the colored and the white races is admitted, but it is suggested that these differences may be due to environmental influences. This does not take into account behavior of the races under circumstances in which each has been free to follow its own bent. For example, the Negroes of Haiti and of Africa have shown scant capacity for building a native culture of a high order. That is perhaps one of the best tests of the innate capacity of a race.

The writer is not very fortunate in the arguments which he uses to indicate that there are scant genetic differences in mental capacity between the races of Europe. About 5,000 public school children in the State of Massachusetts whose parents were born in foreign countries were given mental tests. Fourteen national groups were involved. In spite of the fact that all of these children were born in the United States, their achievements on the mental tests gave their national groups approximately the same relative positions that the Army Mental Tests revealed. Arguing that these differences are not racial, but rather disparities between national groups, Professor Freeman attempts to test the hypothesis of race inequality by dividing each national group into its supposed racial components. Each national group is sub-divided into Nordic, Alpine, and Mediterranean sub-groups according to whether the hair color and eye color are light, medium, or dark, respectively. It was found that within each national group these sub-groups did not show significant differences in mental performance, and from this it is argued that there is no evidence here of racial differences. The argument is invalid. For example, an Italian with light hair and eyes is under no suspicion on genetic grounds of necessarily having a complex of inherited mental characteristics which are very frequently found in north Germans, for example. As a consequence of the segregation and recombination of genes, an Italian might be fair-skinned, light haired, and blue-eyed, and at the same time carry a majority of those genes affecting mentality which characterize the Italian race. The data as far as they go tend to substantiate the view that there are marked differences between groups, rather than to support the contention that such do not exist.

One of the most interesting features of the work is the discussion of the influence of age on mental capacity. Mental ability rapidly increases during the first eighteen or twenty years of life. Freeman suggests, though nowhere in his book does he prove it, that this mental growth may be facilitated and extended by the intellectual discipline of formal schooling. In one table it is shown that in a group of 617 adults the average mental age between 15 and 19 was 17.5. This decreased slightly to 15.11 at the ages 50 to 54. When the age period 80 to 84 was reached, the mental level had dropped to 11.6, a decline of nearly 6 years of mental age. Such a drop does not seem to be found in every one, however,

for persons of high mental caliber who maintain their intellectual activity throughout life show a lesser decline with advancing years. Furthermore, the slight mental deterioration of late middle life does not preclude notable accomplishment at this period, for accumulated experience and knowledge have the effect of offsetting the relatively small decline of capacity.

This is a timely work. The writer believes that genetics has been so much occupied with the study of traits whose hereditary determination is rigid, that it has neglected to analyze those instances in which the development of the organism is conditioned not only by the genes but by surrounding circumstances. The reviewer agrees with Freeman that the individual is to be regarded as the product of two categories of agencies, genetic and environmental. That Freeman perhaps over-emphasizes in places the importance of the latter, does not seriously detract from the value of his work. Differences of opinion in regard to such matters can be resolved not by argument but by critical experimentation.

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THE NATURE OF PLANT CHIMAERAS

THIS volume* should appeal both to the botanist and to the layman interested in understanding chimaeral phenomena. It is the only treatment in English which presents the subject from its general aspect. It gives a fairly adequate discussion of the important investigations in the field. The book is well written and has a number of very useful illustrations.

For the benefit of the reader who is not acquainted with the facts, the subject is treated first from its theoretical side and later from the standpoint of the experimental results obtained by investigators. To the reader who is conversant with the subject, the new interpretations placed upon some of these results will be thought provoking to say the least.

The first chapter outlines the characteristics and problems of the chimaera, which term is made to include any plant with a "composite genetical nature, however the composite structure may have arisen." The second chapter outlines the "chimaerical hypothesis." The original investigations of Baur on *Pelargonium* are also detailed. In the subsequent pages the reader is impressed with the comparative ease with which the diverse experimental data on variegated leaves, etc., are interpreted in terms of this hypothesis. Simply stated, it accounts for the chimaeral patterns found in the mature organs of plants by assuming that they are developed from growing points which are also composite. Roots exhibit an exception to this rule as is pointed out in chapter six.

The third and fourth chapters give an alternative hypothesis, designed to account for certain products obtained by grafting, as well as the investigations of Winkler and others on the genus *Solanum*. According to this "graft-hybrid hypothesis," a fusion of the genetically different nuclei of stock and scion is assumed to occur. As a result of such a fusion, shoots which show a blending of the parental characters, may arise at the point of union. Careful rechecking of these alleged cases of "graft-hybrids" has failed to yield any conclusive evidence in favor of the hypothesis. Baur's interpretations on the other hand may be used adequately to explain the situation in *Solanum*, as well as in other genera discussed in chapters five and seven.

A number of interesting points

*Jones, W. Neilson, *Plant Chimeras and Graft Hybrids*. Price 3s, 6d. Methuen's Monographs on Biological Subjects. Methuen and Co., Ltd., London, 1934.

bearing on the origin, by somatic mutation, of chimaerical forms and chromosomal chimaeras, etc., get very little space and are relegated to the last chapter.

The interpretations which the majority will get as a result of reading this book will undoubtedly be helpful in arriving at a better understanding of the chimaeral forms which are met with by every student of botany.

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✣

"Who's Who" Among the Genes

AN organized search for the very best existing strains of plant and animal life has been begun by the United States Department of Agriculture in cooperation with the 48 State agricultural experiment stations, foreign genetic institutions, and private plant and animal breeders.

One of the first results of this search, Secretary of Agriculture Henry A. Wallace explained today, will be the assembling of what might be called a "Who's Who in American Plant and Animal Life." This will be a catalog of plant and animal germ plasm proved to be superior for such important characters as productivity, resistance to disease, and ability to transmit desirable characteristics.

A second result of the organized search, Secretary Wallace believes, will be to emphasize the as yet unrealized possibilities of breeding research and to suggest improved methods for such research. In certain plant forms, the geneticist has already made remarkable progress; but in others, and in most classes of livestock, scarcely a beginning has been made.

"I trust the day will come," Mr. Wallace declared, "when humanity will take as much interest in the creation of superior forms of life as it has taken in the past in the development of superior forms of machinery."

The first step in this organized search has been to obtain from every section of the United States, and from abroad as well, detailed genetic information on every major plant and livestock form. A departmental committee under the chairmanship of O. E. Reed, chief of the Bureau of Dairy Industry, and including Dr. A. F. Blakeslee of the Department of Genetics, the Carnegie Institution, is now assembling and analyzing a mass of data from the state experiment stations and others. The product of this exhaustive survey and analysis will appear in the 1936 Yearbook of the Department of Agriculture and will require probably 300 pages in that book. This inventory of superior germ plasm will then be available to scientists and farmers everywhere.

The next step in the Department's program will be to concentrate on these plant and animal problems most capable of solution by genetic improvement and to discover effective research methods. The final step involves more efficient distribution of superior germ plasm to those plant and animal breeders who are prepared to make use of it.

Although this is a long-time program, certain to encounter defeats as well as successes, Department scientists believe it will have a profound influence upon American agriculture. They point to what plant breeders, particularly, have already accomplished in the United States and abroad. A high proportion of our acreages of grain crops and fruit and vegetable crops, among others, is annually planted to varieties developed by the geneticists for superior productivity, for resistance to disease, or for drouth or frost resistance.

Progress has been slower in livestock development, it is admitted, because of the longer life cycle involved, the high cost per unit, and the difficulty of measuring productivity. . . . . It is hoped that the Department's program can ultimately make possible as much progress in livestock breeding as has already been achieved in plant breeding.

Press Release, U. S. Department of Agriculture.
April 16, 1935.

HERITABLE CHARACTERS IN MAIZE

XLIX—Pale Midrib

R. A BRINK*

As a more complete body of facts regarding the hereditary composition of the plant is being built up the usefulness of maize for genetic research is gradually being enhanced. Ten linkage groups, each of which has been associated with a particular chromosome in the set of ten, have been established. A large number of characters suitable for studies on inheritance have been discovered, and steady progress is being made in assigning these to their respective positions in the linkage groups.

The skeleton maps emerging from this work represent, so to speak, the beginnings of a topographic survey of the maize genom. The mapping procedure of the geneticist differs in an essential respect, however, from that of the surveyor. The latter can first locate his boundary lines and then describe the position of the important features within in terms of them. The geneticist, on the other hand, does not know beforehand what the limits of each linkage group are. He must start from some internal point and plot the genes found in their positional relations to each other, trusting that as the number of loci identified increases he eventually will have covered the entire range of the group.

The important evidence which McClintock† has obtained regarding the position in the chromosomes of certain genes whose map relationships have been established shows that significant progress in this direction is being made. By examination of plants of appropriate genetic composition and carrying a terminal deficiency McClintock found, for example, that the A_1 gene, which occupies an end position in the current map of the A_1-Rg_1 linkage group, is located toward the end of the long arm of chromosome 3. Similarly lg_1, which has been placed at one end of the B-lg_1 linkage group, is located close to one end of chromosome 2.

The limits of the linkage groups corresponding to certain chromosomes, however, are probably still far from being reached by the present maps, to say nothing of the many unmarked gaps between recognized loci. Maps adequate for many genetic purposes would call for enough marked loci in each chromosome so that no double crossing over could escape detection. Much further work is required before this objective will be attained. There are many characters satisfactory for genetic purposes yet remaining unplaced, and new ones are being discovered every year. It does not appear likely, therefore, that the student of maize linkage will lack for material for some time at least. The limiting factor in extending the maps at present is rather the time required to place the genes already in hand.

The Pale Midrib Character

The pale midrib character was found in the breeding plot at the University of Wisconsin in 1930 in a once selfed line of Golden Glow, a local variety of yellow dent corn. It is a simple recessive to the normal type, the heterozygote being indistinguishable phenotypically from the homozygous dominant. It is proposed to apply the symbol "*pm*" to the pale midrib gene.

*Papers from the Department of Genetics, Agricultural Experiment Station, University of Wisconsin, No. 183. Published with the approval of the Director of the Station.

†McCLINTOCK, B., 1931. Cytological observations of deficiencies involving known genes, translocations and an inversion in *Zea mays*. University of Missouri, *Agric. Exp. Sta. Res. Bull.* 163, 30 pp.

PALE MIDRIB INVOLVES A NEW TYPE OF CHLOROPHYLL REDUCTION IN THE PLANT

Figure 8

A pale midrib plant (*A*) compared with a normal sib (*B*). It will be noted that along the midribs and in the sheathes of the leaves on the pale midrib individual less chlorophyll is present than in the normal type. The "pale midrib" character is dependent on a recessive gene located on chromosome 3.

In families segregating pale midrib, the character can be clearly distinguished somewhat before the plants are half-grown. The tissue along the midrib of the leaf becomes chlorotic, the central pale area merging gradually into the green portions on either side. The lower leaves show the most pronounced effects. In them the chlorophyll may fade out almost to the margin at the base of the blade and in a steadily narrowing band to the tip of the leaf. The midrib is ivory colored or greenish-ivory rather than light green as in normal individuals. The leaf sheath, likewise, becomes distinctly pale in color. These characteristics are illustrated in Figures 8 and 9.

DETAIL OF PALE MIDRIB

Figure 9

This is a closer view of the pale midrib plant shown in Figure 8. The sheath and the middle part of the blade are ivory colored or greenish-ivory.

The *pm* gene delays development somewhat and reduces the stature of the plant about one-quarter. The viability is satisfactory for most genetic purposes. In combination with *na* (nana), *pm* gives a moderately thrifty plant, although Rg_1pm (ragged, pale midrib) individuals are weak, possibly on account of extreme reduction in the photosynthetic area. In the latter type of plant the *pm* character is easily recognized by its effect on the color of the leaf sheath. In *pm* individuals pollen production is approximately normal, although the ears are small and sometimes abortive. In these regards, however, *pm* compares favorably with a large number of characters which maize geneticists have found widely useful.

Linkage Relations

The *pm* gene is located in the A_1-Rg_1 linkage group, which corresponds to chromosome 3. In Table I the results are given on three families from backcrosses of the type,

$$\frac{na\ Pm\ Rg_1}{Na\ pm\ rg_1} \times na\ pm\ rg_1.$$

The amounts of recombination shown are as follows: *na-pm*, 33 per cent; *na*-Rg_1, 38.5 per cent; *pm*-Rg_1, 8 per cent. This establishes the order of the genes as *na-pm*-Rg_1, with the crossover relations as depicted in the chromosome map in Table I. Although a direct test has not been made it is probable that *pm* lies close to the ts_4 (tassel seed-4) locus.

Summary

A new gene in maize, pale midrib (*pm*), which causes a reduction in the amount of chlorophyll along the midrib and in the sheath of the leaf is reported. Pale midrib is readily distinguished from the allelomorphic condition and shows satisfactory viability. The *pm* gene lies in the A_1-Rg_1 linkage group (chromosome 3), and shows 33 per cent crossing over with *na* (nana) and 8 per cent with Rg_1 (Ragged-1). The gene order is *na-pm*-Rg_1.

TABLE I. Data of crosses involving $\frac{na\ Pm\ Rg_1}{Na\ pm\ rg_1} \times na\ pm\ rg_1$, **and a chromosome map showing the linkage relations of the three genes (pale midrib, nana, and ragged) in group 3.**

Progeny Number	Rg_1				rg_1				Totals
	Na		na		Na		na		
	Pm	pm	Pm	pm	Pm	pm	Pm	pm	
L1665	35	1	36	0	1	44	2	14	133
L1666	43	6	51	0	3	74	10	27	214
L1668	41	6	38	1	1	71	9	16	183
Totals	109	13	125	1	5	189	21	57	530

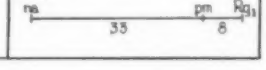
Crossing over percentages

na-pm = 33

na-Rg = 41

pm-Rg = 8

CHROMOSOME MAP OF na-pm-Rg_1



A RECESSIVE CURLY-HAIR CHARACTER OF THE NORWAY RAT

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*Boston, Massachusetts**

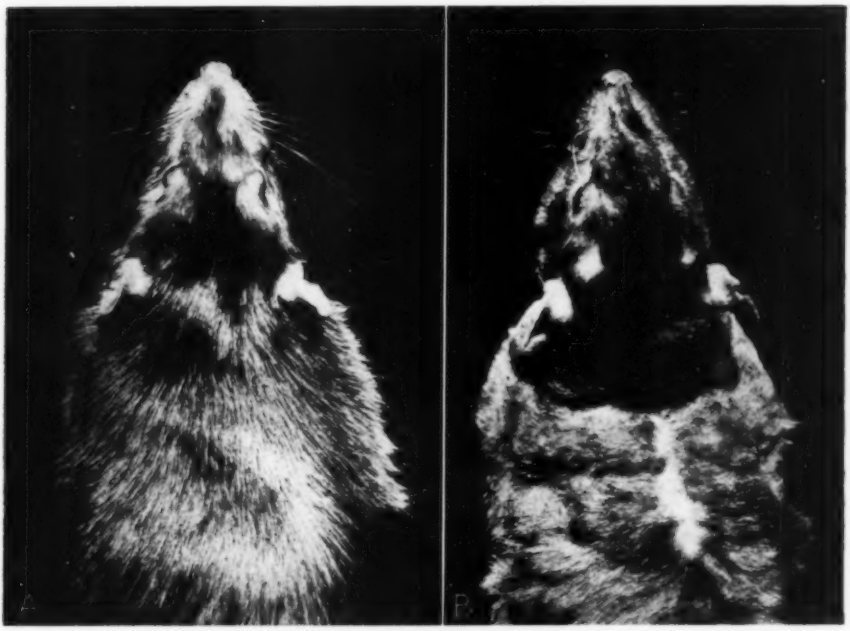
WITHIN the last five years the literature has contained records of several hereditary types of curly hair which have been observed in man and in the lower mammals. Two distinct cases of very curly or woolly hair, characteristic of ulotrichous races, were reported recently by Mohr[5] and by Schokking[7], in human European stocks which showed no evidence whatever of race crossing. In each case the woolly hair was inherited as a simple dominant over the straight type of hair. Among the laboratory rodents a variety of broadly similar variations has been observed. In the rabbit three distinct mutations, termed rex, have occurred. One has been described by Castle[1]. They are inherited as recessive types. The house mouse has produced at this writing two distinct curly hair mutations, one of which has been reported by Crew[2] and the other by Keeler[3]. They, too, are recessive to normal in heredity. A dominant curly hair character has occurred in the Norway Rat and was reported by King[4]. Recently a dominant woolly hair character was reported in a stock of domestic swine in Brazil by Rhoad[6].

The writer had bred a non-agouti stock of Norway rats, *Rattus norvegicus*, originally obtained from Doctor H. R. Hunt, of Michigan State College, for several generations by the mating of brothers and sisters. One of the females of the third inbred generation, ♀ 1786, had been bred, like her three sisters, to each of her three brothers. With one of these, ♂ 1790, she produced six normal females and two normal males, in addition to a male which developed a very distinctly curly coat. She and her litter mates, mated *inter se*, produced in a total of 128 young this single unusual individual, ♂ 2279. These results indicate that the recessive mutation had probably occurred in the germinal tissue of one of the two great grand parents of this male. It is possible, however, that it had occurred in a cell generation somewhat preceding maturation of the germinal tissue of one of his two grand parents. The relative scarcity of the mutant gene in the generations to which ♂ 2279 and his parents belonged favors the latter view. He and his brothers and sisters were mated in all of the possible combinations. One of his sisters and both of his brothers were demonstrated by this method to be heterozygous for the new character, which is illustrated in Figure 10.†

The new recessive curly coat character, which may be designated kinky, with the symbol, *k*, is a very striking deviation from the normal type. From the first, the hairs over the entire body, including the vibrissae, are markedly curly or kinky. The juvenile pelage is shorter, appears very dense, and is of a woolly texture to the touch. The adult pelages are somewhat shorter and rougher than normal. In the kinky rats over six months of age regeneration of hair does not seem to keep pace with an excessive breakage of the hair. As a result bare spots appear, particularly on the shoulders and hips. The behaviour of the curly haired rats seems to indicate that their coat is of less value in conserving body heat than is the normal, straight type. Their growth, fertility and duration of life are obvi-

* A contribution from the Laboratory of Vertebrate Genetics, University of Michigan.

† Doctor Clyde E. Keeler, Harvard University, very kindly made the illustrations which accompany this paper. He also acquainted the writer with his new rexoid coat character of house mice by permitting examination of his manuscript and specimens. The writer is grateful for this help.



NORMAL AND CURLY HAIRED RATS

Figure 10

The normal type of hair coat in the rat (*A*) is compared with the recessive, kinky form (*B*) which appeared in the third generation of Norway rats. The curly nature of the vibrissae and the curly, short, irregular coat render this character a striking parallel to the curly mice recently reported in the JOURNAL and to the curly rex character in the rabbit. The hairs tend to be oval in shape as are the hairs of some of the other curly forms reported in the JOURNAL.

ously below normal. A comparison of cross sections of the hairs from kinky rats with those from normal, straight haired individuals shows a greater average difference between the large and small diameters of the former. That is, the hair of the kinky rats tends to be more flattened in shape. The difference is not constantly great in all hairs examined from any two rats, for some hairs from the kinky haired rats tend to be as round in cross-section at some points along their length as those from normals.

Comparison with Dominant Form

Through the kindness of Doctor Helen Dean King two individuals of her dominant curly strain of Norway rats were received for examination. A general comparison of the hair character of homozygous curly individuals of the two strains reveals very slight differences. It appears probable, however, that the recessive type is more uniformly evident through the life of the individual than is the dominant. The curl of the latter tends to become indistinct in the early adult pelages. As Doctor King notes in her report, the dominant curly type of rats shows the curl in a rather incomplete state between the ages of thirty and two hundred days. This variability with age of the curly character probably indicates that the most vigorous pelages, those of young adults, are able to overcome in a large measure the destructive effects of the gene. A comparison of the coats of rats heterozygous for the dominant curly gene with those of rats heterozygous for the recessive kinky

gene shows a marked difference between them. The former show a curly tendency while the latter are entirely straight.

A general similarity is evident between the curly and kinky genes of the Norway rat and the mutations altering hair form in the rabbit and house mouse. The kinky character of rats has much in common with the rex types of rabbits. The rex genes of rabbits appear to produce somewhat greater deviations from the normal coat. The thicker undercoat characteristic of the rabbit tends to obscure the parallel effects of the variations, however. The kinky gene of rats, on the other hand, produces a more conspicuous variation than the wavy genes of the house mouse. It has in common with the rex and wavy factors the property of being recessive to normal. The dominant curly character of rats bears a more marked similarity to woolly hair characters of man and swine with respect to its dominance over the normal.

The recessive, mutant, kinky hair-type has been observed in breeding tests of several kinds at this writing. Sufficient observations have not been made to determine whether this gene gives unusual gametic ratios with any of the other genes of the Norway rat, thereby supplying evidence of genetic linkage. Homozygous kinky rats, *cucu kk*, were mated with homozygous curly *CuCu KK*. The offspring, double heterozygotes, *Cucu Kk*, were curly coated and numbered 62. They produced *inter se* a total of 459 curly coated and 161 straight coated young. This result is a close approach to 13/16 curly to 3/16 normal which is expected in an F_2 generation from a combination of a dominant variation with a similar recessive type. The appearance of normal coats in this F_2 generation is evidence that the two mutations are not allelomorphic. The frequency of the normal individuals would indicate that the two genes causing the curly coat are on different chromosomes. Among the curly coats of the F_2 generation there was much more variability of the curliness than is present in the kinky character alone. Part of this may have been due to an interaction of the two factors. The several degrees of curliness were not tested as to their constitution for the two mutations. It is possible that the genetic type, *CuCu kk*, homozygous for both mutations, was not observed. If the combination is not lethal, however, approximately thirty-eight individuals of that type would be expected in a population of this size and composition.

Homozygous kinky *kk* rats were mated with several other mutant types. The recessive mutations red-eyed dilution, blue dilution, hairlessness, and hooded piebald were used in these crosses. The offspring in each case showed a reversion to the normal condition of the kinky gene as well as of the other gene involved. These results indicate that the kinky character is not allelomorphic with any of these characters. In several of these crosses the kinky rats were females. The fact that they produced non-kinky offspring of both sexes is evidence that the kinky character is autosomal and not sex-linked.

Summary

A recessive, curly coat character of the Norway rat is described. It involves a new, autosomal locus designated kinky (*k*).

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